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REPRINTED FROM THE
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THE PROCESS OF REPAIR AFTER RESECTION OF THE INTESTINE AND INTESTINAL SUTURE.

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THE following experiments were performed chiefly for the purpose of studying the process of repair as exemplified by the peculiar conditions which surround a wound of the intestinal walls, but also with the hope of contributing something of interest, and, perhaps, of value, to the surgeons and investigators who are now occupied with this interesting field of surgery.

The operations upon animals were performed in the Physiological Laboratory of the Harvard Medical School. Strict asepsis was not attempted in all cases, partly because the tolerance of the peritoneum of dogs is so great that precautions are not necessary to secure prompt union of the bowel and abdominal walls, and partly because it was desired to observe the effects of localized inflammation upon the function of the sutured intestine.

As a rule, the abdomen was shaved and scrubbed with a one per cent. solution of carbolic acid, or a one to five thousand solution of bichloride. The animal was covered with towels wet in the bichloride solution, and the portion of abdominal wall left uncovered was sprinkled with powdered iodoform. Sponges were kept in a hot bichloride solution, and instruments in the carbolic solution.

Females were usually selected for these experiments, as it would have been well-nigh impossible to keep an aseptic dressing upon this region of a male.

The omentum was either drawn up, or an incision was made

directly through it. The bowel to be resected having been drawn out through the wound, was held by the hands of an assistant, and protected with hot cloths and sponges. The segment selected for removal was about two to three inches in length usually, and included the area supplied by one mesenteric branch. A ligature was placed around this vessel at its origin, and the intestine and a V-shaped portion of omentum were severed by the scissors. The anastomosing branches were then secured by ligature. These branches can be also conveniently tied before resecting the bowel.

The material used for the suture was the finest sewing silk, armed with a needle fitting closely upon it.¹ The needle is better short, as an unduly long needle is apt to bend or break. As it is not the purpose of these investigations to test the value of any particular form of suture, it will not be necessary to refer to the different varieties that have been invented from time to time.² The "interrupted Lembert" was used in nearly all the experiments. On two occasions a suture devised by Dr. H. W. Cushing, of Boston, which he describes as the "right-angled continuous suture," was employed.

It was not attempted in all cases to penetrate the submucous fibrous layer, as recommended by Halstead, and in but one instance was there a failure to hold the wound, by which is meant that one only of all the stitches taken failed to hold. There did not appear to be any difficulty in avoiding perforation of the mucous membrane; no signs of such an occurrence were observed in any of the specimens.

The first stitch was taken through that portion of the bowel which had no peritoneal covering, namely, that portion lying between the reflected layers of the mesentery. The sutures were continued around the bowel at intervals of about three mm. The mesentery was then sewed with the ordinary interrupted suture.

Suture of the intestine, as has probably been observed by every experimenter, is much more difficult in dogs than in the

¹ "Parabola gold-burnished Sharp's, No. 10."

² Boston Med. and Surg. Journal, January 6, 1887. Dr. Otis K. Newell.

human subject, owing to the tendency to extreme eversion of the mucous membrane, due to the powerful retraction and contraction of the longitudinal and circular muscular layers. This is, at times, sufficient to close the lumen of the bowel so that the contents escape with some difficulty. After a little experience, fifteen minutes were found amply sufficient to perform the suture.

Occasionally it was found necessary to reinforce the sutured wounds at one or two points, but as this involves the curling in of a deeper rim of inverted wall, it is as well to make the first row of sutures as accurate as possible.

The suture complete, the bowel was carefully washed and returned as nearly as possible to its natural position in the abdominal cavity.

No suture of the omentum was made in case it had been cut through. The abdominal walls, including all the layers, were then brought together with stout silk sutures, about eight in number, and the edges of the wound were more accurately adapted here and there with a few superficial sutures. The wound was then dusted freely with iodoform, after a thorough washing, and was either allowed to remain uncovered or was dressed with borated cotton, held firmly in place by a double spica bandage, which was firmly sewed together. This dressing was not changed for a week, but iodoform was dusted on daily around its edges.

In all cases the wounds united by first intention; there was, however, a tendency to suppuration about those sutures which were uncovered by a dressing. No difficulty was found in getting good antiseptic results when all precautions were carefully followed out.

The treatment consisted in starvation for three days, followed by an almost exclusively milk diet.

The following cases have been selected to show the process of repair, under varying conditions, during six months following the operation. In no case did the animal die of the operation.

THREE DAYS.—Bull terrier bitch, medium sized ; no antiseptic precautions ; about one inch of small intestine resected. The continuous Lembert suture was used, one needle and thread only being employed for intestine and mesentery. A little iodoform was dusted on before and after closing the incision in the abdominal wall. The animal was fed on milk, and did well, bowels acting normally ; in three days the animal was destroyed. The wound of the abdominal walls was clean and without discharge, having been kept in good condition by the animal itself ; on pressure, a drop or two of slightly reddish serum could be pressed from the openings of the sutures. The walls were firmly united ; the bladder, which was distended at the time of the operation, was adherent to the inner surface of the wound.

The sutured point was concealed by a mass of indurated and matted omentum, which laid over it and glued together several adjacent coils of intestine. No sign of the sutured mesentery could be seen. The intestines, though coiled and twisted together, admitted water to flow freely through the lumen.

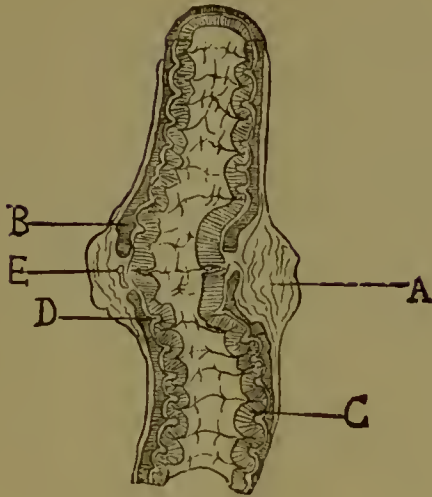
EIGHT DAYS.—Medium-sized mongrel bitch. Fair antiseptic precautions ; incision in median line ; omentum drawn up, and two inches of intestine resected. Ends of intestine united by Dr. Cushing's continued suture. It is interesting to note that, after this suture is completed, no sign of the thread can be seen. A continuous suture of mesentery was also made. An antiseptic dressing was applied after closure of abdominal wound (iodoform, boracic cotton, and bandage).

At the autopsy the omentum was found adherent to and concealing the line of suture ; slight matting together of an intestinal loop by a mesenteric adhesion. The lumen was pervious, and union of the sutured intestine was firm and complete.

EIGHT DAYS.—Medium-sized mongrel bitch. Resection of about four inches of intestine, with corresponding mesentery. Ends of intestine united by interrupted Lembert stitches, and mesentery united by continued suture. The animal had no bad symptoms.

At the autopsy it was impossible to find the exact seat of suture, owing to an extensive matting together of the intestines, which were coiled together in a large lump around the resected spot. It was only after much tearing apart and cutting of the adhesions that the point of suture could be found. The specimen (Fig. 1) from this animal shows a thickening of the peritoneal covering over the line of excision in the form of a callus.

FIG. 1.



LONGITUDINAL SECTION OF INTESTINE EIGHT DAYS AFTER SUTURE, SHOWING AN EXTERNAL CALLUS. THE MUSCULAR COAT HAS RETRACTED SLIGHTLY, AND NO INTERNAL RIDGE IS SEEN.

- A. Thickened peritoneum.
- B. Muscular coat.
- E. Suture.
- D. Fibrous coat.
- C. Mucous coat.

FOUR DAYS.—Longitudinal wounds were made in the intestine of a dog at short distance from each other, two of these being linear incisions, and the third made by cutting out with curved scissors a portion of the intestinal wall. One was united with the interrupted Lembert suture, the other by continued sutures. On stitching the last wound the calibre of the intestine was greatly reduced in size, so that an instrument not larger than a No. 12 English catheter could have been passed through it.

Considerable matting together of the intestines was found at the autopsy, but the lumen at the narrow point seemed to have been restored. On laying open the intestine threads of the continuous suture were found hanging from the wound into the intestinal canal. There was a hole in the intestinal wound from which a portion of the intestine had been removed extending through the walls of the bowel. There was no protrusion of the coat of the intestine inward; on the contrary, a distinct furrow was found in the mucous membrane marking the line of the wound in each case.

NINE DAYS.—A large bitch; antiseptic precautions. Incision through the omentum. About two inches of intestine resected, together with a V-shaped portion of mesentery. Mesentery first sewed up with continued suture, and the intestinal ends united by an interrupted Lembert suture. The animal suffered considerably, necessitating two subcutaneous injections of morphia, after which there were no bad symptoms; the bowels acted well before it was destroyed.

No signs of adhesive peritonitis; the line of the suture in the mesentery was distinctly seen, and the intestine at the point of suture was easily separated from the overlying omentum. There was no narrowing of the calibre of the intestine. At the point of suture a faint wrinkle merely of the mucous membrane marked the line of the incision.

The specimen shows the results obtained by a carefully adjusted suture, not including too much of the intestinal wall, and the careful asepsis preserved.

EIGHTEEN DAYS.—Irish setter; antiseptic precautions. An incision was made in the median line, the omentum drawn up, and a piece of intestinal wall about one inch long and three-quarters of an inch wide was excised with curved scissors. The edges of the wound were united longitudinally with the continuous Cushing suture; owing to the retraction of the circular fibres the calibre of the sutured gut was reduced to the size of a pen-handle when returned into the abdominal cavity. Two inches lower a smaller piece was removed, and the edges brought together transversely by the same suture. Antiseptic dressing, which was changed on the eighth day, when the stitches of the abdominal wound were removed, it having healed firmly.

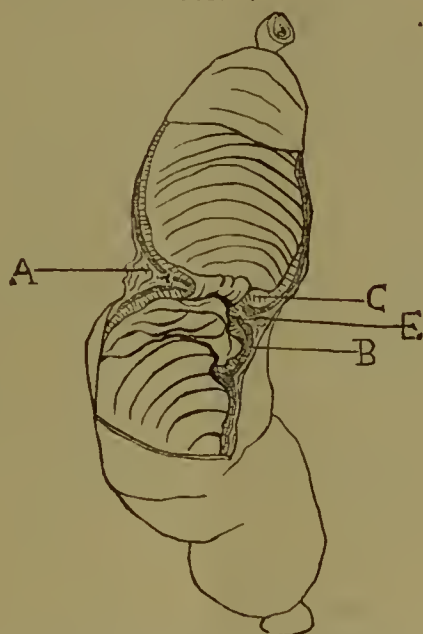
The animal was destroyed on the eighteenth day, being in good condition, passing feces, and feeding well. An adhesion of the omentum was found at one point of the intestinal cicatrix. Some adhesions were found on the mesentery, which folded that part of the intestine, including the two wounds, into a long, oval loop. The narrowing of the first wound still remained nearly the same as at the time of suture, and there was a distention of the bowel immediately above by accumulated food. The other wound had united so neatly that the size of the intestine was perfectly preserved, and it was with some difficulty discovered.

THREE MONTHS.—Large-sized, male pointer; antiseptic precautions taken, but no attempt at antiseptic dressing to the wound. About

three and a half inches of intestine were resected at a point about twelve inches from the cæcum, and a corresponding piece of mesentery. Interrupted suture to the intestine, and continued suture to the mesentery.

The wound united well, slight suppuration occurring from the tracts formed by some of the sutures, which rapidly healed on their removal. For some weeks after the operation the animal appeared to suffer pain, and barked almost continuously, at times vomiting food. These symptoms, however, gradually disappeared, digestion became good, and the bowels regularly moved by normal fecal evacuations. It was noteworthy that, though during the last two months of life its appetite was voracious, it did not gain flesh.

FIG. 2.



LONGITUDINAL SECTION OF INTESTINE, THREE MONTHS AFTER SUTURE. A RIDGE OR DIAPHRAGM NARROWS THE CALIBRE OF THE INTESTINE AT THE POINT OF SUTURE.

- A. Peritoneal coat.
- B. Muscular coat.
- C. Mucous coat.
- E. Point of suture.

At the post-mortem examination the omentum was found slightly attached at the lower portions of the abdominal cavity; one of the adhesions was attached to the intestinal cicatrix, which was further obscured by a matting of the intestines, not only of immediately adjoining portions of the tube, but also of a loop some twelve inches

nearer the stomach. This mass of matted intestines was in close proximity to the cæcal valve, which, however, was not involved. The mesenteric cicatrix was concealed by the matting of the parts.

On opening the intestine at the point of cicatrization, a high ridge was found encircling the wall, at some points higher than at others. The appearances suggest an unintentional increased inversion of the intestine as the suture proceeded. The diaphragm found at this point, and the extensive adhesions of the intestines no doubt accounted for the symptoms of obstruction which were present during the weeks following the operation.

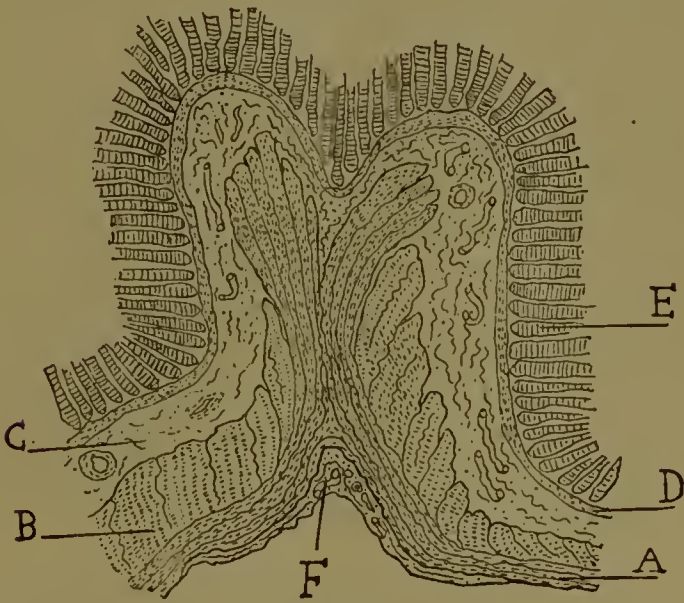
A portion removed for microscopical study showed a proliferation of the peritoneal layer, and also an activity of the cells in the muscular layer. The mucous membrane had closed over the edges (Fig. 2).

SIX MONTHS.—Good-sized spaniel (male). The intestine was resected at a point about one foot from the pylorus; no dressing applied. Eight days later the wound, which had firmly united, was reopened to establish the fact of a localized matting of the intestines. On introducing the finger into the abdominal cavity, a hard, irregular, nodulated mass was felt, which was with difficulty lifted from its bed out of the abdominal cavity, it being necessary first to divide numerous omental adhesions. The mass was found to consist of a coil of intestine so adherent that the point of ligature could not be seen. The mass was returned, and the wound closed again. There appeared to be no intestinal obstruction, it being possible to squeeze gas from the intestine above to that below the point of ligature. There was also no appreciable distention at any point. Six months later the animal, which was in perfectly good condition, was destroyed. The abdomen was opened by a circular incision, which included the cicatrix. On lifting this up the intestines were found uncovered by omentum, which had apparently disappeared. It was found, however, that the entire intestinal canal, from the point of suture to the cæcal valve, had escaped through the opening in the omentum which was made at the time of the operation. The intestine could easily be returned through this opening, and it was then found that the adhesions noted as existing one week after the resection had almost entirely disappeared. The omentum, as in all cases, was adherent to the linear cicatrix in the bowel, and a slight narrowing of one portion of the mesentery was observed, due to a cicatricial contraction. The suture in the mesentery was distinctly seen in its whole length. On distending the bowel

with alcohol, and opening it after hardening, a considerable narrowing of the calibre was found at the point of suture, due to so great inversion of the intestinal walls. Owing to narrowing of the mesentery at one point, a kink was formed, when the intestine was distended, and produced a marked spur interiorly, narrowing the calibre at that point.

A microscopical examination of a portion of the cicatrix, removed for the purpose, showed an intimate blending of the bands of longitudinal fibres of the muscular coat, which suggested strongly a union of this coat by a reproduction of muscular tissue (Fig. 3).¹

FIG 3.



SECTION OF CICATRIX AT SIX MONTHS (SEE FIG. 2, E). THE VARIOUS COATS HAVE UNITED, EXCEPT THE CIRCULAR FIBRES, WHICH HAVE RETRACTED SOMEWHAT.

- A. Longitudinal muscular fibres.
- B. Circular muscular fibres.
- C. Fibrous layer.
- D. Submucous muscular layer.
- E. Mucous membrane, shown in part only.
- F. Thickened peritoneal layer.

Case of strangulated hernia operated upon by Dr. M. H. Richardson. The hernia was first operated upon five years before by injection for a radical cure. The relief had been complete until the day before the operation by Dr. M. H. Richardson. The sac was opened and

¹ These experiments were performed in the Physiological Laboratory of the Harvard Medical School, with the assistance of Dr. G. H. Monks.

the loop of intestine reduced. The symptoms not being relieved, the abdominal cavity was opened four days later and a reduction *en bloc* found with sloughing intestine. The gangrenous portion was excised with a corresponding portion of the mesentery. The much greater facility with which the suture (the Lembert) could be applied than in the dog was very noticeable, owing to the absence of eversion of the mucous membrane. The patient died twenty hours after the operation. The patient was a female, aged sixty-five. The hernia was inguinal.

At the autopsy it was found that the obstruction which existed during life had not yet been entirely relieved, the upper portion of the intestine remaining distended. Matting of the intestine had also occurred in this case.

Dr. W. Wotkyns Seymour's case of pistol-shot wound of the abdomen.¹ The patient, a boy aged sixteen, was operated upon, about twelve hours after the injury was received, in a basement tenement, but with all the antiseptic precautions. Blood and feces were found in the abdominal cavity. Two inches and a half of the transverse colon were resected, and two wounds in the mesentery were sutured, as also a nick in the duodenum. The patient died at the end of twenty hours. Union was found to be perfect at the autopsy, no leakage occurring through the sutures. There was some evident folding of the mesentery and colon from the adhesive peritonitis, which was stated to have existed in the report of the autopsy.

The following specimens are taken from the Warren Museum to illustrate certain points alluded to in this paper.

Specimen No. 919 shows a matting together of the intestines from adhesive peritonitis or from a congenital condition. The patient was sixty-five years of age, and suffered from chronic diarrhœa and disease of the kidneys. There were no symptoms of obstruction noted in the report of the case in the records of the Massachusetts General Hospital.

Specimen No. 4758½ shows the condition of the intestine of a young man who died more than a year after passing a piece of intussuscepted bowel² seventeen inches in length. Persistent vomiting continued afterward, and at the autopsy a constriction was found at the point of cicatrix above which the intestine was much dilated.

¹ New York Medical Journal, August 21, 1886.

² Boston Med. and Surg. Journal, December 28, 1876.

Such a specimen as this suggested the possible results that may follow a circular suture of the intestine, should considerable contraction of the cicatrix subsequently take place.

CONCLUSIONS.—As it was not the purpose of these experiments to test the different kinds of suture, little need be said on this point. In applying the interrupted suture it was found easy to invert a larger amount of intestinal wall than is desirable, and, as has been observed by other experimenters, there is an increased tendency to invert as the suture proceeds. Neither of these difficulties was met with in the case of resection of the human small intestine reported above. The suture appeared to be much more readily applied in this case owing to the absence of eversion of the mucous membrane, and the greater calibre of the bowel prevented undue narrowing of the lumen.

The right-angled continuous suture when applied is completely concealed and holds the edges of the wound firmly together. It has the advantage of avoiding numerous knots which tend to increase adhesive inflammation, and is drawn tighter by increased distention of the bowel. In the case of any suture, however, which inverts the coats of the intestine a valve-like action of the wound is produced, and the greater the distention of the bowel the more firmly are the edges of the wound pressed together.

In one experiment, not here recorded, the intestine was removed immediately after suture (interrupted) and forcibly distended with water, but no leakage occurred owing to this action. In applying any continuous suture, a certain amount of care and attention is required on the part of the operator to keep the stitches tight during its application. This necessitates the use of one hand solely for this purpose, which, however, does not constitute a serious objection. Moreover, failure to secure firm coaptation at any point can be remedied by applying an interrupted stitch at that spot. The continuous suture, it is rightly claimed, becomes tighter with distention of the bowel, but this supposed advantage, so far as holding the edges

of the wound is concerned, is offset by a tendency to prevent a dilatation of the wounded bowel when relief to obstruction is desirable.

The rapidity with which adhesion takes place tends to equalize the holding qualities of different sutures, they being all rapidly buried under the reparative material.

Unless strict asepsis is preserved, suture of the intestine is followed by numerous adhesions of peritoneal surfaces in the neighborhood of the wound. In some cases this is so extensive as to conceal entirely the sutured intestine, so that it is difficult to find in the mass of matted intestine. It would seem difficult for intestinal contents to pass through such a tangled coil, but in no case was there any material obstruction to the flow of fluid injected at one end. Such a condition may exist in the human intestine without symptoms of obstruction, as is shown by Specimen No. 919, Warren Museum, referred to above. Considerable interference with peristaltic action must, however, exist when adjacent coils are so closely adherent. Should a resection be contemplated at a time when obstruction is already present, as in strangulated hernia, and the indications are not only to remove the sloughing bowel, but also to relieve obstruction, it becomes a question whether intestinal suture or an artificial anus will carry the patient more safely through the crisis.

The conditions favorable for a local peritonitis are already present, and it is probable that adhesions of the adjacent portions of the intestines will, in many cases, take place as in the cases of resection of human intestine reported.

In the case of strangulated hernia the upper portion of the bowel was still greatly distended at the time of death.

When the symptoms of obstruction are the most prominent features of the case and this condition demands prompt and complete relief, it would seem preferable to establish an artificial anus and to suture the intestine later when the conditions were more favorable for recovery.

If strict asepsis has been preserved, little or no adhesion of the bowel or mesentery is seen. This is shown well in the specimen described, where there is no sign of folding or matting

of the intestine and the suture in the transparent mesentery can still be seen (page 8).

In the specimen showing the bowel three weeks after resecting, the mode of casting off of the intestinal suture was observed. The peritoneal surface of the wounds had united firmly, and union of the mucous surface was delayed from being complete by the threads of the continued suture, which, in each case, were hanging from the wound in the interior of the bowel.

This observation suggests the possibility of a delay in the union of the mucous membrane by the casting off of the long thread in the continued suture. In those operations in which only a small portion of the coat has been inverted no ridge was seen in the interior of the gut, but when the amount inverted was considerable the ridge was still observed undiminished in size at three and six months. In the suture of longitudinal wounds of the intestine, this inversion was not observed; on the contrary, a slight groove marked the line of the incision into the mucous membrane.

The inverted coats form a prominent ridge or diaphragm narrowing the calibre of the bowel, and by further contraction of the cicatrix might give rise to symptoms of stricture. Such an unfortunate sequel actually occurred in the cicatrization which followed the healing of the intestine in the case of intussusception reported above. Here we find a circular cicatrix terminating in stricture. Although under ordinary circumstances the wound would not heal in a way to lead to such an unfortunate sequel, it is well to recognize the possibility of such an occurrence if the edges of the bowel are carelessly turned in during suture and excessive local inflammation is not guarded against.

In longitudinal wounds there is also danger of too great narrowing of the bowel, not from inversion of the coats but from loss of a sufficient amount of intestinal wall. In such a case the wounds should be closed transversely instead of longitudinally, the former method resulting practically in a circular suture of the intestine.

Although the peritoneal layer is an extremely thin one and forms a very insignificant portion of the intestinal wall, as seen

in microscopic section, a marked activity of cell-growth is observed on the surface of the coat and the line of sutures, within twenty-four hours probably concealed under newly formed tissue. If the bowel be removed at an early period and sections of a portion of the wound are examined microscopically, a marked thickening of the peritoneal layer will be found enclosing the cicatrix and shutting it off from the peritoneal cavity. A certain amount of cell proliferation will also be found in the other coats, both muscular and mucous. The latter seems to unite promptly, leaving little or no granulation surface exposed in the interior of the bowel. For some weeks after suture the inverted muscular layers lie parallel to one another, but are separated by a line of connective tissue. A certain amount of cell growth may be discovered in these layers, however, during this period. In the specimen examined three months after suture there was evidence of a new growth of muscular tissue in the neighborhood of the cicatrix. In the specimen examined six months after suture interlacing bands of muscular fibre indicated that completed union of the muscular wall had taken place. We found also that the submucous layer was continuous through the cicatrix as a distinct layer. A slight thickening of the peritoneal layer was also found at this period.

The different stages in the process of repair consist, therefore, in a thickening of the outer or peritoneal layer, which covers in the wound even in the mildest forms of reparative inflammation. When the reaction is stronger, adjacent layers of peritoneal tissue are called into aid in protecting the wound, all these external changes subsequently disappear, to a greater or less extent. The mucous coat unites readily, but not completely until the suture is cast off, which event probably occurs about the end of the third or fourth week in the continued suture, and much earlier in the interrupted suture. The repair of the muscular coat is slower still and is not probably complete earlier than the sixth month.